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ABSTRACT

A framework for the education, training, and accreditation of engineering personnel in England, particularly those at the craft/technician level, is proposed. The competence-based core for engineering education and training is endorsed by the Basic Engineering Study Group, and is the result of a 2-year project to address problems of overlap, duplication, and inadequate linkage between courses. Recommendations for implementation, assessment, and accreditation are included, along with suggestions for coordinating agreement on standards. Engineering core aims and general objectives are presented for: communication skills, engineering drawing, design and decision-making, mathematics, engineering science, engineering systems, engineering materials, laboratory and practical work, tools and equipment, measurement and data evaluation, and industry and the social environment. Appendices include: an outline of the development of "Core Competencies in Engineering," a list of the study group members and their affiliations, examples of tasks suitable for competence-based learning and assessment, position statements by six interested agencies, examples of college organization for "core competencies" learning and assessment, and a glossary of terms and list of abbreviations. A bulletin summarizing the report is included. (SW)

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Core Competences in Engineering

HE 019 131

An FEU View

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Dear Sir/Madam

CORE COMPETENCES IN ENGINEERING

I enclose herewith the above document. It is the result of a two-year project initially requested by the DES who were, and still are, concerned with the problems of overlap, duplication and inadequate linkage and progression in FE generally and engineering in particular.

The project (see Appendix 1) comprised a survey of the existing provision; the development, by a representative study group chaired by Board Member Mr Jim Deboo OBE (see Appendix 2), of a discussion document *Core competences for engineers*; the appraisal and amendment of this document by six special conferences, involving some 400 participants from industry and education; further evidence gathering and revision by the study group; and final endorsement by the Board of Management as FEU policy.

The final document is generally supported by the major bodies concerned (see Appendix 5). It has as its main focus a common core of objectives comprising a check-list of entitlement for those who wish to study engineering. It relates strongly to the 'level 1' type courses associated with engineering craftsmen and technicians, but it is not specifically age-related, neither is it exclusive to any particular discipline.

Its characteristics are:

i) it is expressed in terms of competences rather than knowledge content;
ii) it provides a framework to which standards for the total engineering experience, education and training (formation) of an individual may be related;
iii) it provides a basis for rationalisation and accreditation, by and between the award-giving bodies.

Most of the ideas in the document have been tested individually but not collectively. No rationalisation has yet taken place between the examining bodies in this area although the concept of a core curriculum is apparently acceptable. The current Review of Vocational Qualifications will no doubt be seeking ways in which a more unified approach to the 'delivery' of vocational competence can be assured.

This document suggests one way forward. Much work needs to be done and Chapter VII of the document indicates that the FEU is willing to co-operate with others in implementing and evaluating a competence-based core, such as suggested.

We will be disseminating exemplary material illustrating aspects of the core in action; and we will be asking the various bodies concerned how they intend to translate into action the agreed intentions expressed in this document.

In the meantime we record our appreciation of all those who contributed so constructively to this project.

Yours faithfully,

Jack Mansell

JACK MANSELL
Chief Officer

CORE COMPETENCES IN ENGINEERING : A POLICY STATEMENT

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PREFACE

Engineering education has for many years suffered from the fragmentation which has affected much vocational education and training in this country and abroad. The reasons for this are diverse, and for the most part buried in history. Education and training, logically two sides of the same coin, are too often separated into watertight compartments with a consequent loss of both entity and efficiency in the formation process. Similarly, personnel who must possess certain knowledge and skills in common (for purposes of communication if for no other) have been educated in what amounts to total isolation from one another.

Core competences in engineering follows two years' work by an FEU Study Group (Appendix 1), and is offered as a contribution to the ongoing debate on the reform of vocational education and training. Its primary concern is to explore the commonality which is increasingly evident in craft and technician education in engineering, but many of the messages apply equally to other levels of engineering education and indeed to other vocations.

The twin themes of 'competence' and 'core' run through the document - the identification of core (encompassing knowledge, skills, attitudes and experience) enables the functions of the various members of the engineering team to be related, and the competence of the whole to be enhanced. Engineering is concerned above all with competence, in the best sense of the word - in a world in which international industrial competition is becoming increasingly intense, our engineering personnel must be competent to meet the challenge of the future.

My thanks are due to all the members of the Study Group (listed in Appendix 2). The extent to which we have achieved a common understanding and a positive outcome is reflected in the position statements by the various bodies represented on the Group (Appendix 5). It is my sincere hope that the progress which has been made will be carried forward by these organisations in their future plans, both individually and in concert.

J A W Deboo, OBE, C.Eng., Chairman of Study Group
September 1985.

I INTRODUCTION

1. This policy statement proposes a framework for the education, training and accreditation of personnel employed in engineering occupations, particularly those at the craft/technician level. It derives from the FEU consultative document Core competences for engineers, the many responses to that document, and the discussions which have taken place in national and regional seminars and elsewhere since its publication (see Appendix 1).

2. The aims of this document are to:

   (i) present a suggested competence-based core for engineering education and training which has the support of the bodies represented on the Basic Engineering Study Group;

   (ii) make recommendations for implementation, assessment and accreditation;

   (iii) suggest means whereby the various bodies responsible for validating and examining engineering education and training might achieve co-ordination of provision and agreement on standards.

3. One of the most encouraging aspects of the responses to the consultative document was the indication that parts of the proposals are already current practice in places in both colleges and industry. It is therefore intended to publish a selection of current examples of good practice in engineering education and training to complement this policy statement and to indicate ways in which others might improve their provision.

4. The rationale for identifying a curricular core in engineering has become increasingly clear in recent years:

(i) Advances in technology are tending to break down the barriers between engineering disciplines; there is now substantial demand for cross-disciplinary personnel*, and traditional craft and technician functional boundaries are less well-defined than in the past**. An agreed core spanning engineering disciplines will facilitate transfer across disciplinary, occupational and other boundaries.

(ii) Engineering personnel are generally required to work in close association with colleagues who may or may not have a similar background and qualifications. Teamwork depends on a common understanding of the nature and purpose of the task in hand and a recognition of the distinctive contribution of each team member. An agreed engineering core will help to establish the basis of such co-operative activity.

(iii) An agreed core curriculum raises the possibility of drawing up a checklist of engineering competences which could be used as a profile, required by all personnel in engineering occupations in order to complete their education

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* See, for example, Arnold, E and Senker, P Designing the future - the [illegible]ions of CAD interactive graphics for employment and s[illegible]ls in the British engineering industry, EITB Occasional Paper No. 9, 1982; Cross, M. The future of the engineering department in process manufacturing companies, The Technical Change Centre, February 1985.

** Joint Advisory Committee for Engineering Report of the Policy Steering Sub-Committee on 'Schemes for those using Engineering Craft Skills' (The Hargreaves Report), CGLI, January 1982.

and training (or 'formation', to use the term employed by the Finniston Report*).

(iv) The Engineering Council has now formulated its policy on standards and routes to registration** (which includes reference to Engineering Technicians), thus providing a structure for accreditation at the higher levels.

(v) A number of bodies have interests in craft and technician schemes and in pre-vocational education, including BTEC, CGLI, MSC, and the training boards. An agreed curricular framework to which these bodies can relate would be a major advantage.

5. To encompass the full range of engineering education and training, the curriculum must be expressed in terms of the competences required of the personnel employed in engineering occupations. This theme is expanded in the following chapters. While the emphasis here is on the needs of craftsmen and technicians in engineering, the concepts of core and of competence to perform may equally be applied to all levels; indeed such an engineering core only makes sense if it is recognised by all engineering personnel.***

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* Department of Industry Engineering our Future Report of the Committee of Inquiry into the Engineering Profession. (Chairman: Sir Montague Finniston, FRS) Cmnd 7794, HMSO 1980.

** Engineering Council Policy Statement : Standards and Routes to Registration, EC 1985.

*** It is recognised that any core for professional engineers (particularly Chartered Engineers) must incorporate a strong conceptual base of fundamental principles which may be less essential for craft/technician personnel; however Chartered Engineer and craftsman alike must be competent to perform in their respective roles in the engineering team.

II A COMPETENCE BASE

COMPETENCE is the possession and development of the skills, knowledge, attitudes and experience required for successful performance.*

6. In recent years, increased attention has been drawn to the definition and assessment of 'competence' in vocational education and training. Competence in the broadest sense has always been the goal of education, but the co-ordination of education, training and practical experience to ensure the personal development of competence in students/trainees both as practitioners and individuals is often neglected. The Institute of Manpower Studies report Competence and Competition** suggests that some of our industrial competitors are better at this than the United Kingdom.

7. Competence is a complex concept, involving knowledge, experience, transferable and specific skills and attitudes. It is often taken in an industrial context to mean simply fitness to perform a specific task. The FEU takes the wider view that while training in specific competences is a vital and necessary aspect of the formation of engineering personnel, competence for life (including work) should be the ultimate goal of the formation process. In a work context, competence therefore implies the ability to deal with novel, as well as established,tasks.

8. The definition of engineering curricula (education and training) in competence-based terms has a number of distinct advantages:

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* For a more comprehensive discussion of 'competence', see Towards a Competence-based System : An FEU View, paras 10-13, FEU August 1984

** Competence and Competition : Training and Education in the Federal Republic of Germany, the United States and Japan. MSC and NEDO, August 1984.

(i) curricula can be expressed in ways which reflect the realities of engineering practice;

(ii) learning experiences can readily be structured to include or simulate actual industrial activities;

(iii) assessment and the maintenance of standards can be related to clearly stated criteria for satisfactory performance;

(iv) attention can be given to the development of transferable skills* which tend to be neglected or treated in isolation by traditional curricula;

(v) students can more readily see the relevance of their studies to their intended occupation, with a corresponding improvement in motivation, since they are engaged in tasks which apply theory to practice;

(vi) the integration of education and training (between which traditional curricula tend to impost a false dichotomy) becomes a real possibility and is indeed encouraged.

9. To define the curriculum in competence-based terms requires a description of the processes (modes of activity) involved in a given occupation. In generalised terms, it is suggested that the primary processes of engineering are communicating, planning, implementing and appraisal. Similar, if not identical, processes may be identified in other vocational areas and indeed in life roles generally. The four processes are seldom identifiable as discrete activities; in any given task

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* See Appendix 6 for a definition of transferable skill. Typical examples of such skills might be, for instance, adopting appropriate fault diagnosis procedures or dealing effectively with customers or clients.

they are usually to be found in combination. A brief description follows:

(i) Communicating. Includes finding and interpreting information and technical data; defining problems; reading drawings and diagrams; interacting effectively with other people and with quasi-intelligent devices; providing information in an appropriate form by oral and written methods, by drawings or sketches, and by demonstration.

(ii) Planning. Involves designing products, services and workplace layouts; selecting tools and materials; task analysis; organising time and work; testing and evaluation. Enables the optimal use of resources within given constraints. Requires computational and estimating skills, an understanding of the principles of appropriate science and technology, the ability to order ideas and criteria logically and to set them out in diagrammatic form. The review of plans in response to progress monitoring and appraisal is included. Planning activities extend the capacity of the participants in problem solving, creativity, discrimination and decision making.

(iii) Implementing. The process of 'doing' or carrying through a task, translating a plan (and its revisions) into an outcome which may be (for example) a product, report or presentation, or some personal accomplishment. An understanding of and practical skills in the use of appropriate tools, instruments and other equipment are needed, together with a knowledge of the requisite materials, science and systems. Implementing involves preparation, carrying out the task, and checking for completion, including clearing up. Implementing develops participants' ingenuity, persistence, reliability and teamwork skills.

(iv) Appraisal. Acquiring competence requires the ability to assess the adequacy with which objectives have been achieved. Self-appraisal should not be confused with external judgements required for accreditation purposes, although it may be associated with such assessments. Skills of measurement and testing and an understanding of monitoring processes and quality control may be required. In broader terms, a regard for the social, economic, political and environmental consequences of engineering activity is needed. The participants' capacity for judgement, self-awareness, self-criticism, discrimination and generalisation are reinforced.

10. It is suggested that the processes outlined above form the basis of competence in engineering occupations, and therefore underlie the competence-based curriculum. The next chapter develops aims and general objectives related to these processes.

III THE CORE

The ENGINEERING CORE is a checklist of competences regarded as essential to the education, training and experience of engineering personnel.

11. The concept of a curricular core of aims and objectives was proposed by the Further Education Unit in A Basis for Choice* and taken up by the CGLI in course 365 - Vocational Preparation (General) and latterly by the Joint Board for Pre-Vocational Education in the CPVE**. It is suggested that the model provided by the CPVE is a suitable basis for an engineering core, and that many of the aims and objectives contained in the CPVE core can be developed in the engineering core. An outline of the CPVE core is provided in Appendix 3.

12. The degree of competence required in the core areas developed here is assumed to be that appropriate to the craft/technician range of activity. A more advanced level of understanding and ability to apply underlying principles, as well as competence in managing an engineering team, is additionally needed by higher grades of personnel. The core has regard to the criteria of the Board for Engineers' Registration of the Engineering Council for registration of Technician Engineers and Engineering Technicians***, and the categories of education, training and responsible experience recognised by the BER are intended to be included.

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* A Basis for Choice, FEU, December 1982

** The Certificate of Pre-Vocational Education Parts A and B, CGLI and BTEC Joint Board for Pre-Vocational Education, January 1985.

*** The Engineering Council : Standards and Routes to Registration, Engineering Council, 1984.

13. The means by which any particular objective in the core is covered in a specific engineering context is not specified here; it is recognised that more mature personnel may have gained experience 'on the job' equivalent to the education/training of a younger person. It is suggested that the total knowledge, skills, attitudes and experience (i.e. the competence) of engineering personnel should be compared with a core checklist which is expressed in terms of processes rather than specific content.

14. The content of the core comprises certain subject areas which are common across engineering disciplines, fundamental principles which may differ in application between disciplines, transferable skills required by all engineering personnel, and generic skills and competences which again may differ in application between occupations. The identification of core elements in the curriculum does not therefore necessarily imply that students can be grouped together for teaching purposes without regard to their specialisms.

15. The definition of an engineering core does not imply a particular order or time in which competences should be achieved, neither are particular aspects of the core necessarily 'level 1'. The core may be regarded as a common theme spiralling upwards through the formation process, with levels of achievement within the core defined in accordance with stage reached and occupational requirements (to the extent that these are known). It is, however, necessary to assume a prerequisite base of personal competence in those embarking on engineering education and training programmes to which the core relates. It is therefore assumed that, on entry to an engineering course, achievement will have been recorded in a common core of basic skills which includes social and life skills, literacy, numeracy, problem solving and planning, and computer literacy. This range of skills is typified by the core of the Certificate of Pre-Vocational Education (Appendix 3). For this reason these skills are only included in the engineering core where a significant

extension of the pre-vocational core is required.

16. It is recognised that for the immediate future it is likely that only a minority of young people entering engineering occupations will come in via the CPVE route. However, performance in the CPVE core may be used as a checklist to assess the readiness of young people to enter vocational education and training in general, and engineering formation in particular. There are other pre-vocational routes which develop equivalent skills and competences, notably appropriate TVEI and YTS programmes. Unless broadening elements are included in the curriculum, it is likely that school pupils taking traditional GCE or CSE examination subjects will have gaps in their pre-vocational experience. Syllabuses in craft, design and technology cover many of the requisite personal skills and competences, however. Young people with extensive experience in TVEI or similar schemes or with a CPVE covering production, technical services or construction modules are likely to have covered significant areas in the engineering core. An essential prerequisite to the successful implementation of this core is therefore some form of initial diagnostic assessment of students to check their level of attainment in the range of basic skills described in the CPVE core.

17. Engineering core aims and general objectives

It is intended that the core skills and competences listed below should primarily be acquired, demonstrated and assessed through the performance of appropriate tasks. It is recognised, however, that some component competences might best be achieved outside the task framework. The divisions used are for classification rather than teaching/learning purposes, and it is likely that objectives in a particular core area will be covered in a number of educational and/or training modules. The aims of the core are expressed as purposes and intentions to be pursued by the student/trainee; the objectives are general

descriptions of activities contributing to the achievement of the aims.*

1. Communicating

1.1 Communication skills

Aim : (i) to acquire communication skills in relation to colleagues, customers, the general public etc;

(ii) to acquire and improve decision making, learning and information retrieval skills.

In the course of carrying out engineering tasks, the student should :

1.1.1 identify information needs, extract relevant ideas and information from books, articles and other media effectively and efficiently and express them succinctly in graphic, written and spoken form;

1.1.2 write clearly and concisely, with appropriate organisation of content and an adequate grasp of vocabulary, spelling, grammar and punctuation in the context of (i) a personal communication; (ii) a formal communication (iii) a technical report; complete forms and questionnaires; observe and record data and procedures systematically, accurately and in a suitable form;

1.1.3 give, listen to, understand and respond appropriately to verbal messages of a technical nature; communicate effectively by

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* The level of attainment in particular objectives is not specified here, but should relate to occupational requirements.

telephone; contribute effectively and appropriately to discussion of a technical problem; deal effectively with customers and clients; select and use appropriate media for communication;

1.1.4 retrieve information from technical reference sources, including libraries and research organisations, and by means of Prestel and other electronic data retrieval methods;

1.1.5 interpret technical specifications, and read and interpret data in tabular, algorithmic and graphical form.

1.2 Engineering drawing

Aim : to acquire competence in producing, reading and using engineering drawings and diagrams.

In the course of carrying out engineering tasks, the student should :

1.2.1 read, interpret and use engineering drawings and diagrams employing B.S. conventions and symbols, relevant to an appropriate occupational area;

1.2.2 make dimensioned sketches, working drawings and circuit diagrams manually and using a CAD package.

Other skills involved in communicating appear under objectives

2.1.1 to 2.1.3	3.2.4	4.2.3
2.3.1 to 2.3.5		4.2.4
2.4.1, 2.4.2		
2.5.1 to 2.5.4		

2. Planning

2.1 Design and decision making

Aim : (i) to acquire and improve individual and team planning, decision making and design skills;

(ii) to acquire competence in interpreting and using technical information, data, specifications and software.

In the course of carrying out engineering tasks, the student should:

2.1.1 work effectively as a team member and as an individual on an assigned task involving planning, decision making and problem solving;

2.1.2 draw up a design brief from given requirements and constraints; draw up a plan of work; suggest, consider, investigate and evaluate alternative solutions in an ordered and logical manner; interpret data and results;

2.1.3 operate a microcomputer or computer terminal using appropriate software packages (e.g. database, word-processing, CAD facility) with sufficient confidence to show some familiarity with a keyboard and elementary appreciation of programming techniques.

2.2 Mathematics (Note : the mathematics skills included here, together with those contained in the Numeracy area of the CPVE core, are suggested as a minimum for competence in an engineering function)

Aim : to acquire competence in using mathematical principles to illustrate and solve engineering problems and perform engineering tasks.

In the course of carrying out engineering tasks, the student should solve problems which require him/her to :

Numerical manipulation

2.2.1 evaluate expressions involving integer indices and appreciate the fundamental relationship between indices;

2.2.2 use a calculator to perform calculations involving basic arithmetic operations, reciprocals and indices on whole and decimal numbers, giving answers to an appropriate number of significant figures; convert to and from standard form;

2.2.3 develop and test a program to perform a repetitive engineering calculation or use a software package for this purpose (including iterative and numerical methods);

2.2.4 make valid estimations and approximations of the numerical solutions to physical problems when appropriate;

Measurement and shape

2.2.5 interpret area as proportional to $(\text{length})^2$, volume as proportional to $(\text{length})^3$; estimate and calculate perimeters and areas of simple plane figures including the circle, volumes and surface areas of simple solid shapes including the sphere;

2.2.6 construct right-angled, similar and congruent triangles, solve right-angled triangles for angles and length of sides, use and interpret the trigonometrical ratios sine, cosine and tangent;

2.2.7 use the geometric properties of circles relating to circumference, radius, tangent, chord, secant, sector, segment and arc of circle;

2.2.8 sketch commonly encountered curves and appreciate the reason for their shape : circle, parabola, ellipse, hyperbola, sine and cosine;

Algebraic methods

2.2.9 generate, simplify and factorise algebraic expressions using the basic notation and rules of algebra, including quadratics;

2.2.10 generate, transpose and solve linear equations and simultaneous equations by algebraic manipulation;

2.2.11 in the course of interpreting data, draw and determine the equation of a straight-line graph and use the concept of rate of change of a property as represented by the slope of a graph; appreciate the significance of the position of axes on graphs and of maxima and minima on curvilinear graphs;

2.2.12 use a graphics terminal or plotter connected to a microcomputer to produce graphs and tables with the aid of suitable software;

2.2.13 use the concept of direct and inverse proportionality, including interpreting and using scales on drawings.

2.3 Engineering science

Aim : to demonstrate understanding of and competence in the application of scientific concepts to the solution of engineering problems.

In the course of carrying out engineering tasks the student should :

2.3.1 plan and design activities and laboratory and other investigations in which an understanding of scientific principles involving physical quantities and physical and chemical effects is demonstrated. These could include:

Equilibrium, moments
Force, pressure
Stress, strain
Heat, temperature
Motion, velocity, acceleration
Chemical reactions
Vibration, sound
Electromagnetic spectrum
Radioactivity
Energy, power
Friction, lubrication
Potential difference, current, resistance
Magnetic, heating and chemical effects of electricity
Alternating current, impedance
Conductors, insulators, semi-conductors;

2.3.2 plan and design investigations into the purpose and principle of operation of a number of mechanical and electromagnetic mechanisms, and the law(s) under which they operate in a practical situation;

2.3.3 plan and design electrical and electronic circuits;

2.3.4 plan and design a variety of structures;

2.3.5 specify appropriate codes of conduct and safe working practices.

2.4 Engineering systems

Aim : to acquire competence in solving problems involving engineering systems.

In the course of carrying out engineering tasks, the student should :

2.4.1 plan and design simple electrical, electronic, mechanical, hydraulic and pneumatic systems including systems employing feedback; an appropriate selection from the following systems could be included:

electrical amplifiers, oscillators, power supplies, microprocessor-based control systems, mechanical transmission systems, pneumatic and hydraulic power and control systems (Note: except in specialist areas, it is suggested that a 'black box' approach is appropriate);

2.4.2 specify appropriate codes of conduct and safe working practices.

2.5 Engineering materials

Aim : to acquire competence in determining the use of common engineering materials including metals, ceramics, polymers and composites, based on an understanding of their properties, characteristics, uses and forms of supply.

In the course of carrying out engineering tasks, the student should:

2.5.1 obtain information concerning the characteristics of materials used for production, manufacture, insulation and protection and materials specific to given design applications; use a materials database;

2.5.2 discover the properties of materials in use; determine when materials testing is necessary or prudent (e.g. required by law) and select property(ies) to be tested (See 3.1.7);

2.5.3 justify the choice of particular materials for given applications and select materials appropriate to particular applications, taking into account forms of supply, availability, cost, properties required; forming, cutting and joining (including adhesive) processes; effects of heat treatment and important interactions between materials with respect to degradation, corrosion, pollution, toxicity; surface coatings for insulation and protection purposes;

2.5.4 identify the hazards of materials properties, including the effect of (i) the environment on the material (ii) the material on the environment (iii) materials and materials processing on people; specify codes of conduct and safe working practices.

Other skills involved in planning appear under objectives

1.2.1	3.2.1 to 3.2.3	4.1.1 to 4.1.3
1.2.2		4.2.2

3. Implementing

3.1 Laboratory and practical work

Aim : to acquire competence in the conduct of technical investigations and tests.

In the course of carrying out engineering tasks the student should :

3.1.1 conduct laboratory and other technical investigations in which an understanding of scientific principles is demonstrated (see 2.3.1);

3.1.2 construct apparatus and equipment requiring an understanding of the purpose and principle of operation of a number of mechanical and electromagnetic mechanisms, and investigate the law(s) under which they operate in a practical situation (see 2.3.2);

3.1.3 construct and use electrical and electronic circuits, check continuity and verify measurements of potential difference and power dissipation (see 2.3.3);

3.1.4 construct and test a variety of structures (see 2.3.4);

3.1.5 assemble and use simple electrical, electronic, mechanical, hydraulic and pneumatic systems including systems employing feedback (see 2.4.1);

3.1.6 use standard test procedures to determine relevant physical properties of materials; appropriate tests might be selected from the following categories:

tests of mechanical properties (e.g. tensility, hardness) tests of electrical properties (e.g. resistivity, insulation) environmental tests (e.g. corrosion resistance) thermal tests (e.g. insulation, combustibility);

3.1.7 adopt appropriate codes of conduct and safe working practices; act responsibly in potentially hazardous environments.

3.2 Tools, equipment and processes

Aim : to acquire competence in the safe, efficient use of tools, machinery, equipment and processes for manufacture, assembly, construction/erection, maintenance, repair and testing. Particular

students may bias their studies towards a particular occupational area but should recognise the transferability of skills to other areas.

In the course of carrying out engineering tasks, the student should:

3.2.1 select, use and maintain an appropriate range of tools, machinery and equipment currently employed in engineering manufacture, assembly, construction, maintenance and repair appropriately and confidently;

3.2.2 use an appropriate range of forming, shaping, material removal, joining, assembly and constructional processes;

3.2.3 use heat treatment, surface preparation and finishing processes;

3.2.4 select appropriate tools and equipment and assemble and dismantle components in an installation, construction/erection and/or maintenance/repair context, working in an orderly and well-planned manner; use repair and maintenance manuals, charts and algorithms;

3.2.5 adopt appropriate codes of conduct and safe working practices; act responsibly in potentially hazardous environments.

Other skills involved in implementation appear under objectives

1.1.1 to 1.1.5	2.1.1 to 2.1.3	4.1.1 to 4.1.5
1.2.1, 1.2.2	2.3.1 to 2.3.5	
	2.4.1, 2.4.2	4.2.7
	2.5.4	

4. Appraisal

4.1 Measurement and data evaluation

Aim : to acquire competence in the use of measuring instruments and the handling and evaluation of measurements and other data.

In the course of carrying out engineering tasks, the student should:

Statistics

4.1.1 collect, tabulate, check, summarise and interpret simple statistical data, distinguishing between discrete and continuous data, and between a sample and a population, and using the concept of frequency; plot histograms; use as appropriate concepts of spread and central tendency, including range, mean, mode, median, standard deviation (excluding detailed calculation);

4.1.2 use simple probability theory to determine the likelihood of events (e.g. in quality control, reliability monitoring);

Measurement

4.1.3 select and use basic equipment for measurement;

4.1.4 connect up or install and use an appropriate selection of instruments, read and interpret measurements of a variety of physical quantities appropriate to engineering work, quality control and fault diagnosis; devise and use tests to check the validity and degree of accuracy of measurements;

Diagnosis and evaluation

4.1.5 undertake functional checks and fault diagnosis of assembled engineering systems and products;

4.1.6 evaluate the results of experimental and practical work.

4.2 Industry, environment and society

Aim : to acquire an appreciation of the context in which engineering activities are carried out in terms of the industrial and social environment.

In the course of carrying out engineering tasks, the student should:

4.2.1 show an awareness of the national and local range and distribution of industry, the reasons for this distribution, and the way it is organised;

4.2.2 in planning, designing and evaluating products and services, show an appreciation of the constraints of time, cost of resources, processes and overheads, and social and economic factors affecting marketing as related to a relevant product or service;

4.2.3 show an awareness of organisational structures and procedures in an industry or company, including management functions and responsibilities, the role of trade unions and professional associations;

4.2.4 show an awareness of potential sources of friction and conflict in industrial relations and among workmates, and show maturity, sensitivity and good sense in relationships with others;

4.2.5 show an awareness of the sources and utilisation of energy and other resources for industry, including trade-offs between energy and other costs for specific industries;

4.2.6 show an appreciation of the current state of knowledge and likely future trends in areas of science and technology relevant to the student's actual or intended occupation;

4.2.7 participate in projects in which effects of technology and technological change on industry, society and the environment are encountered.

Other skills involved in appraisal appear under objectives

1.1.1 to 1.1.5	2.1.1, 2.1.2	3.1.3, 3.1.4
1.2.1	2.5.2 to 2.5.4	3.1.6
		3.2.1, 3.2.4

IV PROGRAMME DESIGN AND IMPLEMENTATION

18. It has been pointed out (para.15) that the core may be regarded as a theme running through the formation process; it is therefore inappropriate to treat it as a monolithic block of skills to be mastered before progression is possible. The core does not constitute a course in its own right; it is suggested however that course design should include checking against the engineering core to ensure that the core competences are included sufficiently often in the formation process to achieve an appropriate standard. This implies that educational and training programmes should not be considered in isolation, but treated as complementary or integrated functions which together with appropriate experience are required to develop competence.

19. In order to achieve co-ordination of the total formation process of all engineering personnel, a national initiative is required. This issue is being addressed by the Engineering Council (inter alia) for engineers who fall within their remit; for others employing engineering skills and requiring certification of the total formation process, recognition is still problematical. An associated issue is the question of whether current industrial definitions of personnel are being rendered obsolete by advances in technology and working practice. Further consideration is given to these matters in Chapter VI.

20. Although a national framework is required for the recognition of competence to ensure national standards and transferability, detailed programme design and implementation must be carried out locally, to ensure relevance and make best use of local resources. The starting point for programme design must be the competences required in the student/trainee's intended occupation. These should not be interpreted in too narrow a sense; research by City and Guilds into the common engineering skills* and by the EITB

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* Hargreaves Report, see para. 4(ix).

into engineering functions* for example indicates that a considerable range of competences (reflected by the range of objectives in the core suggested in para. 17) is required.

21. It is suggested that, in order to achieve competence, learning tasks should be constructed using the framework of the processes of communicating, planning, implementing and appraisal, covering the various aspects of the engineering function. A complete suite of such tasks, which may be carried out as appropriate in either college or industry or a combination of both, should for each individual student/trainee cover the complete core to an appropriate standard of performance. Mature students/trainees may be found to have previous relevant experience which allows accreditation of parts of the core without requiring further learning.

22. The suite of tasks should include activities which develop the core objectives to the level needed by the student/trainee and his or her employer. For example, more extensive coverage of mathematics and science than is indicated in the core objectives may be required to lay the foundations for continuing formation and career progression; for students/trainees in particular industries, detailed coverage of the skills, technologies and working practices of those industries will be needed. There should in any case be a genuine element of negotiation between learner and tutor in determining the tasks to be performed to achieve the core objectives; this helps to ensure that the learning programme is seen by the student/trainee to be relevant and appropriate.

23. It is intended to publish shortly an occasional paper

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* The analysis of certain engineering craft occupations EITB Research Report No. 2, 1971; Professional engineers, scientists and technologists in the engineering industry EITB Research Report No 4, 1975; The craftsman in engineering EITB Research Report No 8, 1980; The technician in engineering EITB Research Report No. 9 1983.

to complement this policy statement, containing examples of current practice in engineering education and training which illustrate the task-centred approach to learning advocated here*. Innovative and stimulating teaching methods have been found to be widespread, although not common, at all levels in schools, further and higher education and industry.

24. Two examples of tasks suitable for competence-based learning in engineering are shown in Appendix 4. Both of these tasks would be suitable for many (although possibly not all) engineering students/trainees, and could be conducted in either a college or industrial environment. It would be quite possible for some tasks to be carried out 'on the job', although under such circumstances an opportunity for reflecting on the knowledge and skills acquired would be needed. It is not suggested that all tasks need to be as complex as the examples given, but over the complete suite of tasks a reasonable balance between the processes of communicating, planning, implementing and appraisal should be attempted. In current engineering laboratory and workshop exercises, there is often insufficient emphasis on the planning and appraisal processes.

25. A task-centred approach to learning calls for a flexibility of education and training provision which is currently seldom achieved. A reallocation of resources is needed, enabling teaching staff to adopt a tutorial mode for the most part, and allowing students/trainees more open access to facilities such as drawing offices, workshops, laboratories, learning resources centres and computer work stations. Classroom tuition in such circumstances takes on a supportive rather than central role, providing structured information and advice when needed. The adoption of a tutorial style of teaching and learning will facilitate the

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*Project No. RP 117a 'Core competences in engineering - examples of good practice'. Project Director : Dr Ian Clements of Crawley College of Technology.

special support needed by minority groups such as mature entrants. In engineering occupations, women at present constitute a minority group; team-based problem-solving activities which emphasise the life-enhancing role of engineering may attract more female entrants.

26. The range of available student-centred learning resources in engineering is constantly growing making more flexible means of delivery possible. For example, a number of the projects sponsored by the MSC's Open Tech Unit promise to deliver materials which will be useful in an engineering context; the FEU is also receiving and co-ordinating the dissemination of software produced by LEAs and colleges under the DES Education Support Grant scheme,* some of which is likely to relate to engineering.

27. All this has staff development implications:

(i) Some teachers and trainers (and students/ trainees!) may have difficulty in adapting to a role which requires them to act more as a facilitator and manager of learning resources than as a fount of knowledge; this may be an attitudinal problem rather than an intellectual one.

(ii) Lecturing is traditionally a highly individual activity; task-centred learning which inevitably integrates traditional subjects is likely to demand a team approach, which may not come easily. Staff in college departments where team-teaching and student-centred learning are already the norm may be able to help here.

(iii) Closer co-operation between colleges and industry may be required to ensure that the

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* Education Support Grants, DES Circular 6/84, 18 July 1984. See also FEU Guidance Notes No 4, 1984.

full range of competences in the core is covered. Secondment to industry of college staff for short periods is one method for enabling educational programmes to include the competences required on the job where appropriate; the pooling arrangements for teacher training facilitate such interchanges.

28. It has been pointed out that greater flexibility of provision will be needed in education and training (para. 25). Local Education Authorities can facilitate this for their colleges by adopting less prescriptive requirements concerning class size and allocation of resources; colleges can adopt more flexible timetabling arrangements; unions, while rightly protecting the interests of their members, can support more flexible learning programmes. The Manpower Services Commission and the examining and validating bodies have a role to play in supporting innovation and encouraging sound education and training methods. Much is already under way; it is suggested in Chapter VII that carefully monitored trial implementation is required before any large scale changes to the engineering curriculum are attempted.

V ASSESSMENT

29. The effectiveness of a competence-based education and training system depends on the ability to measure competence realistically. Since competence is multi-dimensional, it is to be expected that a wide variety of assessment methods will be required for its effective measurement. Conventional written examinations can play only a limited role in such an assessment system, providing information on the student/trainee's grasp of underlying principles and of report writing abilities, for example. However, most engineering activities involve such complex activities as communication with colleagues, designing and planning (often as a member of a team), and using equipment of various kinds, from machine tools to computers.

30. Process skills, relating to the effectiveness of performance, are frequently just as important as product skills, relating to the quality of the outcome*. The assessment of process skills may be more difficult than the assessment of product skills, because :

(i) assessment must take place during task completion, and is therefore paced by the task and time consuming;

(ii) although an inventory of criteria may be drawn up to assist in assessment, there is likely to be a greater element of subjectivity on the part of the assessor than with product skills - this does not necessarily imply that they are any less valid or reliable than traditional assessments however.

31. A further complication is the question of whether the measurement of competence should be separated from the

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* For a discussion of the distinction between product and process skills see Basic Skills, Appendix 8, paras 10 to 12, FEU, 1982.

process of its achievement. A City and Guilds Skill Test is an example of a discrete measurement of competence, and in this respect is a relatively straightforward assessment. Much engineering project work, however, whether carried out in college or industry, is by its nature one-off and unique and assessment is inextricably intertwined with the learning process. Indeed, one of the factors being assessed may be the rate at which the student/trainee learns.

32. Appendix 4 illustrates the type of assessment that might be made of a student/trainee completing the tasks suggested in the previous chapter. It will be noted that most of the items on these checklists of assessment criteria refer to process skills, and that few, if any, can be related directly to a grade or mark except in very subjective terms. Any marking scheme based on these lists would inevitably be interpreted very differently by different assessors, resulting in an aggregate mark of dubious validity. Used as a checklist, however, and marked as satisfactorily completed at the appropriate stage, a statement of overall competence in the task emerges.

33. In order to achieve parity of standards nationwide, clear statements of guidance by the examining and validating bodies and an effective moderation system are required. The necessity to co-ordinate provision (para.19) extends equally to assessment; local assessment procedures are needed for locally designed tasks, but must be related to national criteria and standards.

34. There is a strong argument for the provision nationally of a profile framework in engineering formation, agreed by the major bodies concerned. Such a framework could be based on descriptors of performance in the engineering core, and serve as a checklist of competence. If graded in ascending levels of competence, the descriptors would provide students/trainees with a record of their progress during the formation process, and would thus have value in terms of formative assessment.

35. The construction and use of formative profiles of achievement is not without its difficulties; the construction of the CPVE core profile statement,* which is the most recent and most nearly equivalent statement available, was a considerable undertaking and will undoubtedly have its critics. For such a profile to be reasonably complete, it is likely to be a much more comprehensive statement of achievement than teachers, trainers and employers are accustomed to. However, the information contained should be of real value in certificating competences - if it is not, then it will have failed in its purpose.

36. A further means of demonstrating competence, particularly to potential employers, should be considered. Students in other disciplines, notably architecture and art and design, prepare a portfolio of their work as part of their education and assessment. Certain aspects of engineering education and training are amenable to recording in this form; design work is the obvious candidate for inclusion in a portfolio, but reports of other activities, accompanied by photographs of manufactured items, could be added. Such a portfolio would provide recipients of the profile with assistance in verifying and interpreting its statements.

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* A pilot version of the CPVE core statements was issued in March 1985 by the Joint Board for Pre-Vocational Education under the title A national bank of core competence statements.

VI ACCREDITATION

37. It was pointed out in para. 4(ii) that one of the reasons for identifying an engineering core is the number of bodies involved in the formation process, each with different interests and emphases. The current model of craft/technician education and training has its roots in the 1956 White Paper*; changes in working practice due to advances in technology are rendering this model increasingly questionable. Agreements which now exist between, for example, CGLI and BTEC (separately) and the EITB, and between BTEC and the Engineering Council, relate to this model but provide evidence of movement towards a more unified system of accreditation.

38. A set of profile statements based on the engineering core would enable the competences required in the engineering function to be identified and certificated without necessarily relating to the 1956 model. Such a profile would not necessarily displace existing accreditation arrangements; it could be used in parallel as an additional source of information relating to the competence of engineering students/trainees. It would, however, have the advantage of covering the full range of relevant activities. In order to function as a unifying element in the formation of engineering personnel, it would need to be jointly agreed and accredited by all the agencies concerned.

39. The implication of an engineering profile is that the agencies (BTEC, CGLI, EITB, MSC and the Engineering Council) would need to agree a core and to relate it to all engineering curricula and training programmes within their scope as appropriate. It is possible to express the core statements in fairly general terms to cover the range of engineering functions and disciplines, but agreement would need to be reached in terms of the level of competence to be achieved at a given stage in the formation process.

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* Ministry of Education, Technical Education, Cmnd 9703, HMSO, 1956.

Much work remains to be done here; however, the stage has probably been reached where trial implementation of a pilot scheme on a national basis is required . This would enable the principle of a competence-based education and training system to be validated. Following this, agreement could be reached on the content of a definitive core checklist.

VII THE WAY FORWARD

40. The Further Education Unit has been encouraged by the positive responses to the Basic Engineering Study Group's proposals for a competence-based core curriculum in engineering. It is clear that the time is right for such a core to be implemented. For effective implementation there needs to be co-operation and co-ordination between the various agencies involved because:

(i) implementation of a competence-based core involves the total formation process, including and integrating education and training;

(ii) the lines of demarcation between various categories of personnel in engineering occupations, never very rigid, are becoming increasingly blurred;

(iii) the establishment of national standards and the monitoring of performance in engineering formation against them requires such co-ordination.

41. At the level of craft/technician education and training, to which this policy statement is primarily addressed, the main areas in which co-operation will be required include:

(i) Resourcing - The agencies which hold the purse strings will need to collaborate if a competence-based system of education and training is to be a viable proposition; in particular, this applies to the various government departments involved, notably the Department of Education and Science and the Manpower Services Commission. The recent White Paper on education and training for young people* indicates that such collaboration is

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* Education and Training for Young People, Cmnd 9482, HMSO, April 1985.

intended. Local Education Authorities and industrial interests also have a crucial role in resourcing the competence-based curriculum, and should be closely involved. Both curriculum development and staff development will need to be adequately resourced if progress is to be made.

(ii) Validation and Accreditation - The Engineering Council, BTEC, City and Guilds, and EITB must continue to develop a co-ordinated role here. Joint accreditation of an agreed core of engineering competences is needed.

(iii) Provision - Here further education must continue to play a prominent, if changing, role. FHE staff form the largest and most skilled body of expertise in this country in engineering formation; we neglect this expertise at our peril, and their development and continuous updating must be a high priority nationally. The training function is well-developed in many parts of industry, particularly in the larger and more progressive organisations, and increasing co-operation between educational and industrial interests is essential to make use of the best practice in both.

42. The FEU would be willing to co-operate with the various agencies concerned in the trial implementation and evaluation of a competence-based engineering education/training scheme in craft/technician functions. Both BTEC and CGLI are in the process of revising their schemes in engineering to reflect a more competence-orientated view; there is therefore every indication that the adoption of an agreed core is now a real possibility. The recently-announced Review of Vocational Qualifications* should give a welcome impetus to the move towards a more coherent system of education and training.

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* White Paper, para. 41 (i)

43. There is evidence that a number of college departments and training establishments are moving towards an education/training model based on competence achieved through the performance of appropriate learning tasks; some examples of such activity will be published shortly by the FEU as an occasional paper. Two outline case studies from this project are included as Appendix 6. Widespread publicity concerning current good practice is one effective way of making progress, and colleges and others who have demonstrable success in implementing competence-based education and training provision are invited to contact the Unit with a view to promoting further development.

APPENDIX 1 OUTLINE OF THE DEVELOPMENT OF 'CORE COMPETENCES IN ENGINEERING'

1. There has for some years been concern about the lack of coherence of provision of education and training in engineering, particularly at the basic level and for the range of occupations traditionally designated as 'craft' or 'technician'. In 1982, with the support and encouragement of the DES, the FEU commissioned Dr Reg Rogers, formerly Pro-Director of Hull College of Higher Education, to report on the basic engineering curriculum and the possibility of developing a core. Dr. Rogers' report revealed a high degree of duplication and overlap in the 'level 1' engineering courses available.

2. The Basic Engineering Study Group (Appendix 2) was set up by the FEU in October 1983 to consider this report and to establish a model curriculum for basic engineering. The proliferation of engineering syllabuses, together with the effects of new technology, the advent of new pre-vocational curricula, and MSC's policy for a competence-based system of training, led the study group to devise a core curriculum. This core, comprising a collection of essential competences for engineering, was published in the FEU consultative document Core competences for engineers in July 1984.

3. The consultative document attracted widespread interest in education, industry and elsewhere, and the FEU received a large number of carefully considered responses. A summary of those received by 19 October 1984 is available from the FEU on request.* A national seminar on the theme of the document was held in London

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* Core competences for engineers : a summary of responses received October, 1984. Available from the FEU Information Centre.

on 2 November 1984,* followed by five regional seminars in January and February 1985. Some 400 people representing the full spectrum of engineering education and training were thus able to contribute to the development of the proposals contained in the consultative document.

4. This policy statement represents one of the outcomes of this consultation process. It takes account of the many discussions that have taken place, and reflects both these and the consensus view of the organisations represented on the Basic Engineering Study Group. A brief position statement by each of the bodies concerned will be found in Appendix 5.

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* Report on the national seminar available from FEU Information Centre.

APPENDIX 2 THE BASIC ENGINEERING STUDY GROUP

The Basic Engineering Study Group was formed by FEU with the intention of establishing a model curriculum for basic engineering, primarily related to the initial training of young people, but relevant also to adults. The study group met eight times between October 1983 and May 1985 under the chairmanship of Mr Jim Deboo, OBE.

The full membership was:

Mr J A W Deboo OBE (Chairman)	CBI, FEU Board of Management
Mr L Bill	CGLI
Mr W Bolton	BTEC (until February 1984) FEU Consultant (from March 1984)
Mr C Chapman	BTEC (from April 1984)
Mr R W Chattaway	DES (until 9.12.84)
Mr G Goy	BTEC (for the meeting of 27.3.84)
Mr P R Litchfield	MSC Training Services Division
Mr D Mathews	MSC (until November 1984 then Further Education Staff College). On secondment from EITB.
Mr J K Millington	HMI
Ms M Neal	EITB Researcher (from March 1985)
Mr D Oxley	EITB
Mr C Rigg	Engineering Council (from April 1985)
Dr R H Rogers	FEU Researcher, formerly Pro-Director, Hull College of HE
Mr A G B Woollard	DES (from 12.12.84)
Mr J W Mansell	Chief Officer, FEU
Dr M E Rossiter (Secretary)	Development Officer, FEU

Observer

Dr I Clements	Crawley College of Technology (from March 1985)

APPENDIX 3 THE CPVE CORE

(Extracted from The Certificate of Pre-Vocational Education, published by the Joint Board for Pre-Vocational Education, January 1985, Part B, page 3).

1. The core studies developed for CPVE are intended to reflect the general education to which all young people on courses approved by the Joint Board should have access. They have been described in terms of aims and objectives which can be readily matched to a range of achievement and experiences in a variety of contexts. It is intended that students should address all the aims and that the objectives should be used as a checklist in the planning and evaluation of programmes, and to identify appropriate opportunities for progression. In terms of course design, the aims and objectives should be put together in such a way as to reflect the curriculum as a whole rather than being regarded as discrete activities. Indeed, the acquisition of personal skills, practical skills and those abilities relevant to problem solving, decision making and adaptability which do not normally appear on the traditional timetable are essential to successful development.

2. For the convenience of course designers, the Joint Board has grouped these aims and objectives under familiar headings which relate to content and process but it is stressed that these are not to be regarded as single subjects. It is recognised that there will be overlap between these areas and it is important that this is taken into account when recognising experiences and achievement. The ten areas which make up the CPVE core are described under the following headings:

- Personal and Career Development
- Industrial, Social and Environmental Studies
- Communication
- Social Skills
- Numeracy

- Science and Technology
- Information Technology
- Creative Development
- Practical Skills
- Problem Solving

3. The nature of the CPVE framework recognises that the achievement of core aims and objectives will be met in a variety of ways but specifically identifies the role of the vocational studies as a way in which the core will be developed and applied.

4. The Joint Board will publish further details of these aims and objectives including appropriate learning strategies for the delivery of the core and profile descriptors. From this it will be possible to define stages of development (levels) essential for progression into, throughout and out of the CPVE course.

5. The CPVE certificate will record attainments in all ten core areas.

APPENDIX 4 EXAMPLES OF TASKS SUITABLE FOR COMPETENCE-BASED LEARNING AND ASSESSMENT

(1) Design and manufacture of a storage bin

Assignment Brief	Objectives
Task : To design and make a floor-standing or racked storage bin to hold specified components; dimensions, general specification and cost limit supplied.	
1. **Preliminary** Note important aspects of the specification and any other constraints within which you will have to work. Throughout the task, log all activities and decisions made.	1.1.5 2.1.1 2.1.2 1.1.2
2. **Design and Planning** Sketch, investigate and evaluate alternative designs. Compare materials, tools and processes, cost. Use college CAD facilities to investigate alternative designs. Choose preferred solution, giving reasons. Check availability of materials, tools, equipment. Prepare work plan, working drawings, card model of sheet work.	1.1.4 1.2.1 1.2.2 2.1.3 2.2.2 to 2.2.6 2.5.1 2.5.3 3.2.1
3. **Manufacture** Obtain materials from stores. Mark out, check dimensional accuracy. Cut, form, fasten, finish to specification.	1.1.3 3.2.1to 3.2.5 4.1.3 4.2.5
4. **Evaluation** Check finished product against specification. Is it 'fit for its purpose?' Reappraise design and manufacture in the light of experience. Prepare a brief report, explaining how you would modify the design and the manufacturing method for batch production.	4.1.5 4.1.6 4.2.2 1.1.2 1.2.2 2.1.2

Assessment Checklist

The student:

1. **Preliminary**

(i) Recorded details of specification in a log book.
(ii) Made a preliminary work plan.

2. **Design and Planning**

(i) Collated information about existing designs of similar storage bins.
(ii) Collated information about suitable materials, tools, processes.
(iii) Sketched a number of possible alternative designs.
(iv) Investigated, using computing facilities, alternative designs with regard to specification (including approx. cost), manufacturing capability, general 'fitness for purpose'.
(v) Chose/synthesised preferred solution, stating criteria used.
(vi) Prepared detailed work plan and timetable.
(vii) Prepared working drawings using CAD facilities.
(viii) Produced a card model of sheet metal parts.
(ix) Recorded planning activities in log book.

Manufacture

(i) Obtained materials from stores.
(ii) Marked sheet work out and checked dimensions.
(iii) Cut, formed and fabricated storage bin.
(iv) Applied finishing processes.
(v) Employed safe working practices.
(vi) Recorded manufacturing activities in log book.

4. **Evaluation**

(i) Checked finished product against specification.
(ii) Recorded suggested modifications to design and

manufacturing procedure.

(iii) Reported on modifications required to design and manufacture to suit batch production.

(iv) Prepared a report.

(ii) Design of electrical power transmission line and construction of a working model

Assignment Brief	Objectives
Task : To investigate the design parameters of a National Grid electrical power transmission line and to build a safe working demonstration model using components available from a professional components catalogue. (General specification and route map of the transmission line supplied)	
1. Preliminary	
Note important aspects of the specification and any other constraints within which you will have to work. Throughout the task, log all activities and decisions made.	1.1.5 2.1.1 2.1.2 1.1.2
2. Design and Planning of the Model	
Sketch, investigate and evaluate alternative designs for the working model using CHGB documentation. Compare materials used, input and output potentials (voltages), resistivities of materials, currents, power losses and cost. Use Spreadsheet to investigate the costs of different materials and input and output rms potentials. Use the course database to look up the most commonly available materials, their prices, and their physical and electrical properties.	1.1.4 1.1.5 2.1.3 2.2.1 to 2.2.4 2.2.9 2.2.10 2.3.1
Choose preferred solution to the working model problem giving reasons.	2.3.3 2.3.5 2.4.1 2.5.1

		Objectives
	Check availability of materials, tools, equipment and components. Prepare work plan, working drawings, circuit diagrams and transformer specifications.	2.5.3 3.2.1
3.	**Manufacture of the Model**	1.1.3
	Obtain materials from stores. Mark out, check dimensional accuracy, check component values.	3.1.1 to 3.1.3 3.1.5
	Assemble, connect up, check circuit and test.	3.1.7 3.2.1 3.2.3 3.2.4 3.2.5 4.1.4 4.1.1
4.	**Evaluation**	4.1.3
	Check finished model against specification. Does it adequately demonstrate the relevant principles?	to 4.1.6
	Prepare an explanatory leaflet showing what the model demonstrates and explaining the technical and commercial reasons why the National Grid uses high voltage transmission of electrical power. Collate all paperwork in a file or folder.	4.2.5 1.1.2

Assessment checklist

The student:

1. **Preliminary**

(i) Recorded details of specification in a log book.
(ii) Made a preliminary work plan.

2. **Design and Planning**

(i) Collated information about electrical conduction.
(ii) Collated information about materials and devices.
(iii) Sketched a number of possible designs.
(iv) Used computing facilities to investigate properties of suitable materials.
(v) Used computing facilities to try out various combinations of input and output potentials, conductor diameters and to choose between the available materials.
(vi) Reached a preferred solution stating criteria used.
(vii) Prepared a detailed work plan and timetable.
(viii) Prepared circuit diagrams and working drawings using CAD facilities.
(ix) Recorded planning activities in log book.

3. **Manufacture**

(i) Obtained materials from stores.
(ii) Marked work out and checked dimensions.
(iii) Mounted components and assembled model.
(v) Employed safe working practices.
(vi) Recorded manufacturing activities in log book.

4. **Evaluation**

(i) Checked finished product against specification.
(ii) Recorded suggested modifications to design and manufacturing procedure.
(iii) Related the performance of the model to CEGB National Grid practice.
(iv) Prepared an explanatory leaflet.
(v) Collated paperwork.

APPENDIX 5 : POSITION STATEMENTS BY INTERESTED BODIES

Business and Technician Education Council

1. For the future, if technicians are to have employability, they will need to be versatile and have both the expectation and facility to acquire and use new knowledge and skills. BTEC is committed to the view that this can be met in initial educational terms by developing groups of core studies, around which a variety of cross-disciplinary work can be set.

2. BTEC has affirmed elsewhere its commitment to contribute to the effective operation of the nation's education and training provision and, with the MSC, believes that education and training should, as far as possible, be planned as an integrated, coherent process of learning and developing, so that the trainee experiences them as such. The Council actively pursues opportunities for appropriate liaison. For example :

   (i) with the Engineering Council which identifies BTEC courses and awards as the mainstream route to registration at Stage 1 of the T Eng. and Eng. Tech. registers;

   (ii) with the Engineering Industry Training Board with which BTEC has a joint certification agreement relating to initial formation of technicians in engineering;

   (iii) with the City and Guilds of London Institute and particularly through the Joint Board for Pre-Vocational Education to provide appropriate progression to engineering courses.

3. In arriving at its own recommendations for identifying and incorporating a core in BTEC Engineering programmes, BTEC is taking account of :

   (i) Standards and Routes to Registration published by the Engineering Council;

   (ii) the national debate stimulated by the FEU and the

resultant policy statement;

(iii) responses to the Council's discussion document on educational policy and the resulting Policies and Priorities into the 1990s;

(iv) experience gained by TEC and BTEC since their inception and particularly over the last eighteen months, resulting from industrial and educational consultation, associated with new programme guidelines and units which have reflected similar philosophies to those outlined in (i), (ii), (iii) above;

(v) the Certificate of Pre-Vocational Education.

4. At the macro level, BTEC supports the principles contained in the FEU policy statement for a competence-based core for engineering education and training. Indeed, it has joined with the City and Guilds in making a public statement of support which also cautioned, however, that a number of the specific proposals remain to be tested.

City and Guilds of London Institute

1. In a joint letter on 22 January 1985, the Director-General of the City and Guilds of London Institute and the Chief Executive of the Business and Technician Education Council indicated their broad general support for the FEU document Core competences for engineers and suggested that it now needed testing against a number of roles in traditional and new occupations.

2. The agreed curricular framework for CPVE is now being implemented in many centres, and proposals for piloting possible links with YTS are being discussed with MSC by CGLI and BTEC. The development of routes for progression from CPVE is continuing.

3. The Institute's new scheme for basic engineering competences, now being piloted with the active participation of the Regional Bodies for Further Education in England and Wales, together with the recently developed scheme in computer-aided engineering, includes the curricular structure of Core

competences in engineering. These schemes provide for the initial education and training required for traditional and most recent engineering occupations.

4. Revision of schemes involving competences beyond basic level has begun, again in accordance with the recommendations of the Institute's Hargreaves Committee to which Core competences in engineering makes justly generous reference. Learning tasks will emerge from the pilot phases of these schemes and the proposition that an agreed profile of achievements could be useful will be easier to judge.

5. The Institute remains committed to the competence-base for its schemes and will continue to co-operate with any body which shares that objective.

Engineering Council

1. It is essential for all engineering personnel to be versatile and to be willing and able to keep their knowledge and skills up-to-date. The Engineering Council places great emphasis on the relevance of education and training to industrial, commercial and national needs and the integration of theory and practice.

2. It is noted that this policy statement is concerned mainly with employment at the craft/technician level. Although the curriculum will change at different levels and types of engineering, the Council stresses the importance of problem solving and design to provide the integration of theory and practice. The processes of communication, planning, implementation and appraisal in the FEU policy statement provide a concept that can give this integrated approach. Thus the Council supports the principles contained in the FEU policy statement but would emphasise the need for sufficient resources and the time for the essential development of staff and for the curriculum changes required for successful implementation of this approach to education and training.

3. The Engineering Council is working with the engineering institutions, BTEC, EITB, CITB and other bodies to develop a

co-ordinated role. There are links with CGLI but the roles of the Council and CGLI do not require the same degree of co-ordination at present.

Engineering Industry Training Board (Staff Paper)

1. The EITB welcomes the initiative taken by the FEU in developing core competences in engineering. We are keen to support moves to improve the integration of education and training and we believe that this document is an important contribution to advances in this direction.

2. To achieve implementation of the proposals, existing mechanisms for liaison with industry should be used, such as the working parties and committees of the EITB, CGLI and BTEC. The Board will be pleased to co-operate with the FEU to facilitate such discussions and to integrate the proposals in this document with developments in industrial training in the engineering industry.

3. The EITB has improved the flexibility of its engineering craft training system with the development of module segments. New specifications for first year basic training are competence-based. Thus the EITB's initiatives are, we believe, compatible with the FEU approach.

4. The development of a core and of assessment must be done concurrently and the comments made above about using existing mechanisms of consultation apply equally to assessment. Centres for assessment will need to be developed and, to avoid a proliferation of different standards, the EITB is well placed to act as a national accreditation body for such centres.

5. We believe that the proposals of the FEU and similar developments in competence-based training taking place elsewhere, including the EITB, represent an important step forward in the education and training of engineering personnel.

6. The Board thanks the FEU for the opportunity to involve Board staff in the development of its proposals and looks forward

to a continuing partnership in these important developments in the organisation of the engineering curriculum.

Manpower Services Commission

1. The FEU policy statement on Core competences in engineering is welcomed and we are pleased to support the document and hope its message will receive widespread adoption and implementation.

2. The approach can provide a basis for both the quality and effectiveness of engineering education and training, and in the assessment of individuals. The outcome should be the development of engineering personnel with the appropriate skills and motivation to work in a rapidly changing technical environment.

3. The MSC remains committed to modernising arrangements for training in occupational skills and for both young people and adults, and it is recognised that this approach, set out by FEU, closely relates to the objectives of the New Training Initiative. Furthermore, the document provides significant opportunities for further improving relationships amongst all those bodies interested in the initial and continuing development of engineering staff. The positive contributions made by the examining and validating bodies, industrial training boards, the Engineering Council and others is also encouraging.

4. The test of competence-based approaches will be through their application. Whilst there are examples of its adoption, it now needs testing in a variety of engineering roles and occupations. We therefore anticipate seeing this work reflected in relevant MSC schemes and we will also co-operate and assist, where appropriate, other bodies promoting competence-based schemes.

Department of Education and Science

1. The Department warmly welcomes the work undertaken by FEU on core competences in engineering, and in particular the close

co-operation in this exercise by the major certificating bodies.

2. The report is issued against the background of the major Review of Vocational Qualifications, set up by the Department and the Manpower Services Commission following the White Paper Education and Training for Young People (Cmnd 9482) in April 1985. That review is considering the need to rationalise, and build effective links between, the diversity of qualifications now available, both in education and in industrial training. There are problems of overlap and duplication, and of inadequate linkage and unclear progression routes, at many levels and in many vocational areas. The Department believes that the approach outlined in Core competences in engineering provides useful indicators of a way forward to resolve some of these difficulties.

3. Some key questions raised by the report are for the certificating bodies to consider in the first instance, but also fall very much within the purview of the Review of Vocational Qualifications. These include, in particular, the relationship between 'craft' and 'technician' levels; the concept of 'core', which can be understood in various ways (common blocks of teaching; common content through separate teaching; common 'process' expressed through diverse content; a common, competence-based assessment structure) and needs to be clarified for the benefit of consumers; the concept of 'competence' which can be interpreted by some as reductionist and by others as the only method of ensuring relevance; and the value of task-based learning as a way to describe an individual's performance, enabling a rationalisation of provision for those at different levels and in different specialisms. The report goes some way to exploring all these issues; more work is needed and will fall to the bodies referred to above.

4. The Department recognises that any changes in the structure, approach or emphasis of engineering courses will have staff development implications. These, as far as the education system is concerned, require effort on the part of colleges and LEAs; the Department's in-service training grants for FE staff updating could usefully be exploited to support this.

APPENDIX 6 EXAMPLES OF COLLEGE ORGANISATION FOR 'CORE COMPETENCES' LEARNING AND ASSESSMENT

The two outline case studies given below are drawn from the findings of FEU Project RP177a, 'Core competences in engineering - examples of good practice' (Crawley College of Technology). It is intended to publish a more detailed discussion of these and other examples of implementation of aspects of the 'core competences' proposals in the near future.

Gloucestershire College of Arts and Technology

1. Integration of Core Studies On three craft courses in one centre (CGLI 205 Mechanical, 216 Fabrication and 381 Motor Vehicle) the numeracy, communications, engineering science and materials elements have been integrated for the first two years of the course.

2. Task-centred approach to learning CGLI 205 Mechancial 4th year (19-20 year olds) day-release students work through a set of formal work-pieces in the workshop. The learning outcomes are specified for these structured exercises. There is formal teaching across the syllabus as and when it is appropriate relative to the separate practical exercises. The task-centred approach is of a guided/structured style. The formal back-up tuition is not just 'chalk-and-talk', but often discussion and demonstration based.

3. The craft students (paras 1 and 2) are assessed by CGLI national examinations. It was thought by staff that the integrated approach for the first 2 years and the task-centred approach for the 4th year improved the pass rate and quality of competence in the workplace (as indicated by employer response). For the College appraisal of the 4th year work-pieces, 50% was awarded for the hardware and 50% for the write-up, covering such areas as : interpreting the objectives; anticipating end dates; describing the equipment, techniques, calculations, etc; problems encountered; accuracy of the end product and

explaining discrepancies.

4. When interviewed, students on the 4th year craft course stated that they preferred the integrated approach (they had the 'traditional, separated, approach' the previous years). They had mixed views on team work. One considered the processes were more important than the outcomes; another thought them equally important. Overall there was thought to be little internal (to the student) change in terms of satisfaction, self-confidence or career ambitions.

5. Project work BTEC Diploma in Eng.(Tech) students do a major project in their second (and final) year. At GlosCAT, the four processes of communicating, planning, implementing and appraisal are all explicitly assessed.

6. The project work is assessed in six categories: discovery (20%), synthesis (25%), decision making (10%), initiative (10%), group work (20%), and evaluation (15%).

7. Inserting a similar project into any course not already containing it would cost about £20/student-year in materials, and could occupy from a half BTEC unit (30 hours) to a double unit (120 hours). Many courses are now introducing project units; but there is nothing in BTEC rules preventing the 'theory' units being learnt through project work.

8. General In all these cases, the staff involved were enthusiastically in favour, as perhaps one would expect, given that the innovations would not have come about without their individual dedication. All thought that the more widespread application of their individual approaches would improve learning. However, they were chary about infringing on colleagues' professional independence.

Somerset College of Technology

9. Core initial education and training for motor vehicle trainees Common initial education and training spread over three levels (YTS, Craft, and Technician) using task-centred integrated common modules were noted. There are 3 groups (Technician, Mechanic, Parts & Body), each following the same structure of course on different days:

> Associated Studies (= core skills) - Numeracy & Physical Science;
> Technology (transferable skills), using a student-centred and paced integrated approach;
> FE content is integrated in the above modules, which are relevant for YTS, CGLI 381 or BTEC ONC.

10. Assessment : Processes are assessed, using the RTITB profile as per their Training Record Book. The FE component is done by either CGLI or the usual BTEC methods.

11. Although staff had clearly spent many hours producing excellent material, they were still not wholly satisfied with it - partly because the modules did not cover the whole ability range adequately. The integration of YTS and CGLI is based on the CGLI book Enhancing the Quality of Your YTS Programme - Add City & Guilds. It was thought that a well organised workshop was needed, better than many available in FE colleges, and more time was demanded of the lecturing staff. The staff were very enthusiastic, although they did not believe that there were doing anything particularly advanced, simply implementing established ideas.

12. The Motor Vehicle approach was impressive in both its scope (attempting to generate a 'Schools Project' pack on their own and in their own time), and in its success to date. If staff succeed in guiding most of the target ability range, the output will be very useful elsewhere directly.

13. Integrated Learning approach An integrated learning approach for a one-year EITB off-the-job training plus FE for Mechanical, Production, Electrical and Electro-Optical Technicians, in the workshop topics was noted. For Engineering Materials, Tools, Equipment and processes, a combined Electrical & Mechanical EITB group share two whole days in various workshops (mechanical, sheet metal and welding, electrical). A YTS group follow the same scheme, but with a different timetable. There is an initial series of set-pieces, individually done by everyone, before team-work is embarked on. Working in teams of four, to EITB objectives, they draw, plan, sequence the machining, then do the work, and check it.

14. When interviewed, the students were engaged in producing their individual set pieces. They considered that sharing with another specialism did not make any difference. It was difficult to disentangle their evaluation of college itself (as compared with school) from that of the course compared with school courses. Overall they were in favour of the course. However, they did think that there should be progress assessment. Satisfaction and self-confidence were good, although whether this reflected upon the college or the course, or both, was difficult to say.

15. General Both of these schemes, although requiring a lot of effort on the part of staff, are highly transferable to other institutions and other courses. Senior staff in the college were obviously very impressed by (and supportive of) the work being done.

APPENDIX 7 GLOSSARY OF TERMS AND ABBREVIATIONS

BTEC	Business & Technician Education Council.
CAD	Computer-Aided Design.
CBI	Confederation of British Industry.
CGLI	City and Guilds of London Institute.
Checklist	(of competences) A list describing in abbreviated form the achievements and accomplishments required to demonstrate competence in a given field; a statement of such achievements.
Competence	The possession and development of sufficient skills, knowledge, appropriate attitudes and experience for successful performance in life roles (ref. Towards a Competence-Based System: An FEU view para. 10, FEU, August 1984).
Computer Literacy	A basic understanding of computer systems, terminology and applications enabling the operation of a computer or microcomputer to perform useful tasks.
Core	(of a course or curriculum) A central theme containing essential competences.
CPVE	Certificate of Pre-Vocational Education, administered by the Joint Board for Pre-Vocational Education formed by BTEC and CGLI.
CSE	Certificate of Secondary Education.
DES	Department of Education and Science.
EITB	Engineering Industry Training Board.

Engineer	'One who acquires and uses scientific, technical and other pertinent knowledge and skills to create, operate and maintain efficient systems, structures, machines, plant, processes and devices of practical and economic value'. (Engineering Council) Engineering skills may be needed by personnel in occupations not encompassed by this (very broad) definition. This policy statement deliberately avoids drawing boundaries between specific occupational designations.
FEU	Further Education Unit.
GCE	General Certificate of Education.
LEA	Local Education Authority.
MSC	Manpower Services Commission.
Process	An activity involved in the performance of a task, forming an identifiable, though not necessarily discrete, component. The four processes of communicating, planning, implementing and appraisal are identified in this document in the context of engineering tasks.
Profile	(student) A set of statements describing the level of achievement or competence attained by a student/trainee in a given range of skills.
Skill	The facility to carry out a task or part of a task. - process skill: a skill which is demonstrated in the conduct of an activity rather than in its outcome (para. 30). - product skill : a skill which results in a specified outcome (para. 30) - transferable skill : a skill (process or

	product) of such a general nature that when learned in one context it may also be applied in other contexts (para. 8).
Task	A specified assignment designed to result in a definable outcome.
TVEI	Technical and Vocational Education Initiative, an MSC-sponsored vocationally oriented curriculum development scheme for the 14-18 age group.
YTS	Youth Training Scheme.

APPENDIX 8 **BIBLIOGRAPHY**

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APPENDIX(MR.10)

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Objectives

The objectives for which ***The Further Education Unit (FEU)*** *is established are to promote, encourage and develop the efficient provision of further education in the United Kingdom and for that purpose:*
a) to review and evaluate the range of existing further education curricula and programmes and to identify overlap, duplication, deficiencies and inconsistencies therein;
b) to determine priorities for action to improve the provision of further education and to make recommendations as to how such improvement can be effected;
c) to carry out studies in further education and to support investigations of and experimentation in, and the development of further education curricula and to contribute to and assist in the evaluation of initiatives in further education;
d) to disseminate and publish information and to assist in the dissemination and publication of information about recommendations for and experiments and developments in further education.

FURTHER EDUCATION UNIT

CORE COMPETENCES IN ENGINEERING

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November 1985 *ISBN 0 948621 05 2*

Core Competences in Engineering is the result of a two-year project instigated by the Department of Education and Science, who expressed concern about the problems of overlap, duplication and inadequate linkage between courses in further education generally and engineering in particular.
The project comprised a survey of existing courses, the development by a study group (see back page) of a discussion document _Core competences for engineers_, the appraisal of this document by six national and regional conferences involving some 400 participants from industry and education, and final endorsement of a policy statement by the FEU's Board of Management. The final document has the support of the major bodies concerned. This bulletin summarises its contents. A copy of the full report is available on request.

A common core

The report has as its focus a common core of competence-based objectives for engineering students/trainees. It relates strongly but not exclusively to the formation of engineering craftsmen and technicians, is not specifically age-related, and is not exclusive to any particular discipline.

A core curriculum of this type is needed because:

- advances in technology are blurring the boundaries between engineering disciplines and functions
- the accelerating pace of change requires greater emphasis on transferable skills
- teamwork in engineering depends on common understanding and recognition of members' distinctive skills

- such a core can provide a checklist of competences required for complete formation, against which programmes of training and education can be measured

- an agreed curriculum framework gives a reference point and basis for rationalisation for national bodies (BTEC, CGLI, MSC, the training boards and others) and for local course designers, colleges, trainers and teachers

Competence

Expressing engineering education and training in terms of *competence* is not new; it allows:

- curricula to be expressed in ways which reflect engineering practice
- real or simulated industrial activities to be included in learning experiences
- standards to be related to clearly-stated performance criteria
- transferable skills to be identified, and their development planned more coherently
- students/trainees to see the relevance of their studies to their intended occupation
- education and training to be integrated

All this assumes appropriate definitions of competence. The document identifies four primary processes involved in demonstrating engineering competence, and the core curriculum develops each of these. These processes are communciating, planning, implementing and appraisal.

The core in outline

The design of the core assumes a general competence in *basic skills* (such as provided by the Certificate of Pre-Vocational Education) as a prerequisite. The engineering core is intended to be a *theme* running through the formation process—it is not necessarily at foundation level, nor is it a course in its own right. Competences in the core include the following:

1. *Communicating*
Obtaining, interpreting and using information; communicating orally and in writing.
Reading, interpreting, making and using engineering drawings and sketches.

2. *Planning*
Designing and decision making.
Using mathematics—numerical manipulation, measurement and shape, algebraic methods.
Using scientific principles; planning and designing investigations.
Using systems concepts in problem solving.
Discovering and using the properties of materials.

3. *Implementing*
Conducting technical investigations and using standard test procedures
Using appropriate tools, machinery, equipment and processes for manufacture, assembly, construction/erection, maintenance, repair and testing.
Noting hazards and observing safe working practice.

4. *Appraisal*
Collecting and using statistics.
Selecting and using measuring equipment and instruments.
Diagnosing faults and evaluating results.
Showing an awareness of the industrial environment, of commercial and other constraints, industrial organisation and industrial relations, and of future trends.

Note: This is a summary outline. See *Core Competences in Engineering* for full list.

Programme design and implementation

Core competences in engineering suggests that a national initiative will be required to establish a framework of national standards for all engineering personnel, particularly those at technician level and below. Some local programme design will be needed to ensure relevance and to optimise resources.

The report recommends an emphasis on *task-based learning* and gives examples of suitable tasks. It suggests that a range of tasks, tailored to the needs of each student/trainee, should be drawn up to cover the complete core to an appropriate standard of performance. Tasks could be carried out in college or industry or a combination of both, as appropriate. For tasks carried out 'on the job', however, opportunity for reviewing the knowledge and skills acquired will be needed. Some conventional 'classroom' learning will still be necessary.

Assessment

The effectiveness of the proposed system depends on realistic measurement of competence. *Process* skills, relating to the effectiveness of performance, may be as important as *product* skills, relating to the quality of the outcome. A wide variety of assessment methods is needed—conventional written examinations can play only a limited role. It is suggested that checklists of assessment criteria, such as descriptors of performance, may be sometimes easier and more meaningful to use and interpret than detailed marking schemes.

To achieve parity of standards nationwide, a clear lead from the examining and validating bodies is required. An agreed national profile framework related to engineering formation could serve as a checklist of competence. Wherever possible, this statement of achievement could be accompanied by a portfolio of the student's work.

The way forward

National co-operation and co-ordination is needed in the areas of:

- **Resources**—particularly between government departments and between local education authorities and industry
- **Validation and Accreditation**—between the Engineering Council, BTEC, CGLI and EITB
- **Provision**—between further education, training establishments and employers

There is already some movement towards a unified system of accreditation in engineering education, with agreements between CGLI and BTEC (separately) and the EITB, and between BTEC and the Engineering Council. Further impetus may be provided by the current Government Review of Vocational Qualifications. The stage has probably been reached where trial implementation of a pilot scheme on a national basis is required.

The FEU is willing to co-operate with the various agencies concerned to test means of implementing and evaluating a core competence approach to engineering education and training. Meanwhile, colleges and others who have demonstrable success in implementing competence-based education and training are invited to contact the Unit with a view to promoting further development.

The Further Education Unit is an advisory, intelligence and development body for further education, set up by the Department of Education and Science in 1977, with a remit to 'promote, encourage and develop the efficient provision of further education in the United Kingdom'. Since 1983 the Unit has been a semi-autonomous Limited Company with charitable status.

Some definitions from the document

COMPETENCE is the possession and develoment of skills, knowledge, attitudes and experience required for successful performance. (For a more comprehensive discussion of 'competence', see *Towards a competence-based system: An FEU view,* paras 10–13. FEU, August 1984.)

The ENGINEERING CORE is a checklist of competences regarded as essential to the education, training and experience of engineering personnel.

A TRANSFERABLE SKILL is a general skill which,when learned in one context, can be applied in other contexts.

The Basic Engineering Study Group

The 'Core competences in engineering' programme was developed under the guidance of an FEU study group chaired by Board Management member, Mr J A W Deboo, OBE, who also represented the Confederation of British Industry. Other organisations represented on the group included:

Business and Technician Education Council

City and Guilds of London Institute

Department of Education and Science

Engineering Council

Engineering Industry Training Board

HM Inspectorate

Manpower Services Commission

The full report contains position statements by each organisation.

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